Modeling the Resilience of the Power Grid using an Impulse Response Model

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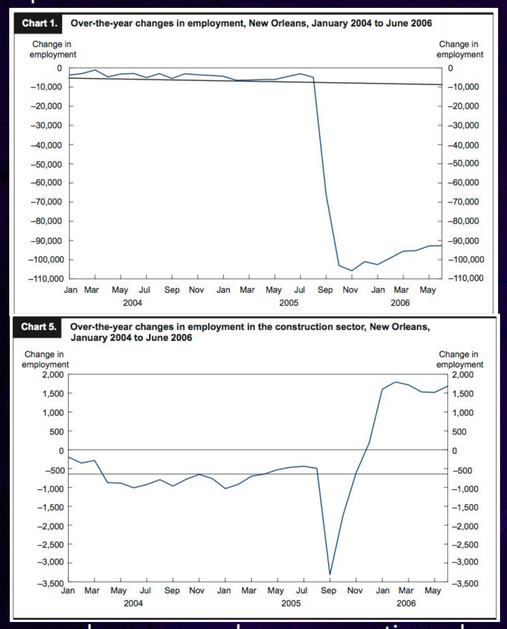
Abstract

How can we design networks that recover quickly?

Resilience can be defined as the ability of a system to return to its original state after some type of failure. This research seeks to model the power grid as a dynamic system and to model failure as an impulse. The impulse represents the damage to the system after the system is damaged by either manmade causes or a natural disaster such as a hurricane. The main idea is that we can't prevent every type of failure, instead we should focus on designing networks that recover quickly. Using the information gathered from our simulation we seek to understand which parameters have the largest impact on the recovery time.

Overview

The goal of the modeling and simulation effort is to develop a better understanding of the dynamics of resilience. We developed a model which describes how long the power grid takes to recover after some type of failure. We then matched the curve to an impulse response curve. Some examples of impulse response curves are:



The first curve shows a very slow recovery time when it comes to employment. The second curve shows how the construction sector was able to recover in just under two months. Our goal is to be able to tweak the parameters in such a way that the time to recover mimics the second curve presented.

Simulation

In this section, we go over the most important components that make up our simulation. Two of these components are nodes, and workers. Nodes represent the generators that failed due to some kind of failure. Workers can be thought of as the resources available to the power grid in order to recover itself.

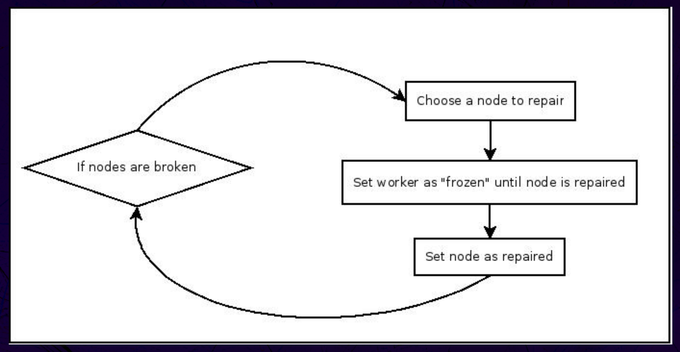
Node Repair Time

There are three main events that affect the repair time of a node:

- Time to repair the node (uniform distribution)
- Delay before starting repair (uniform distribution)
- Waiting time for parts (exponential distribution)

Within our simulation each of these events is assigned a distribution, e.g., uniform distribution. **Each node is assigned a difficulty level which is chosen based on a uniform distribution**, depending on their difficulty level is the time a node takes to repair.

Worker Behavior

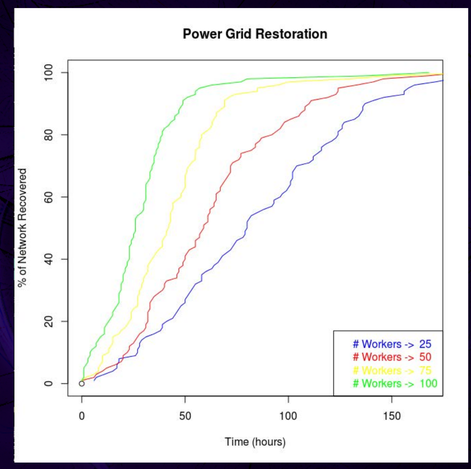


The end result of our simulation is the cumulative distribution function which can be described by the following formula:

$$\int_0^t r(t) * d(t) * w(t)\, dt$$

Where r(t) is the time to repair a node, d(t) is the delay before starting the repair and w(t) is the waiting time for parts.

Results



The above figure shows how a network with 100 nodes recovered after some type of failure. The different curves show how changing the amount of workers improves the recovery time of the overall network.

Changing the amount of workers has a significant impact in the recovery time of the network. For instance, a network with 100 workers was able to recover in around 60 hours, while a network with 50 workers took around 160 hours.

Future Works

- Implement more parameters into the simulation in order to attain a higher level of realism.
- Get real data about power grid recovery time in order to be able to compare simulation results with reality.
- Implement intelligent workers who wont just fix random nodes but use information about their environment in order to make smart choices.
- Develop an economic model in order to understand the trade-of between cost and resource allocation.

Relevant Work

- Comfort, L. "The Dynamics of Disaster Recovery: Resilience and Entropy in Hurricane Response Systems", 2005-2008, Public Organization Review, April 6, 2009
- "Disaster Risk and Resilience", United Nations Task Team on the Post 2015 Development Agenda
- L., M., & Fortier, S. (n.d.). "The effects of Hurricane Katrina on the New Oreans Economy"

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